Determining Pavement Design Criteria for Recycled Aggregate Base and Large Stone Subbase

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AGENCY MEMBERS

➢ MnDOT
➢ Caltrans
➢ MDOT
➢ IDOT
➢ LRRB
➢ MoDOT
➢ WisDOT
➢ NDDOT
➢ Iowa DOT
➢ Illinois Tollway
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- Asphalt Pavement Alliance (APA)
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- Infrasense
- Diamond Surface Inc.
- Flint Hills Resources
- International Grooving & Grinding Association (IGGA)
- Midstate Reclamation & Trucking
- MN Asphalt Pavement Association
- Minnesota State University - Mankato
- National Concrete Pavement Technology Center
- Roadscanners
- University of Minnesota - Duluth
- University of New Hampshire
- Mathy Construction Company
- Michigan Tech Transportation Institute (MTTI)
- University of Minnesota
- National Center for Asphalt Technology (NCAT) at Auburn University
- GSE Environmental
- Helix Steel
- Ingios Geotechnics
- WSB
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- PITT Swanson Engineering
- University of California Pavement Research Center
- Collaborative Aggregates LLC
- American Engineering Testing, Inc.
- Center for Transportation Infrastructure Systems (CTIS)
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- First State Tire Recycling
- BASF Corporation
- Upper Great Plains Transportation Institute at North Dakota State University
- 3M
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- All States Materials Group
- Payne & Dolan, Inc.
- Caterpillar
- The Dow Chemical Company
- The Transtec Group
- Testquip LLC
- Hardrives, Inc.
- Husky Energy
- Asphalt Materials & Pavements Program (AMPP)
- Concrete Paving Association of MN (CPAM)
- MOBA Mobile Automation
- Geophysical Survey Systems
- Leica Geosystems
- University of St. Thomas
- Trimble
OUTLINE

• Follow-up
• Test cells & materials
• Task 7
FOLLOW-UP

• **Task 1** – Literature review and recommendations
• **Task 2** – Tech transfer “state of practice”
• **Task 3** – Construction monitoring and reporting
• **Task 4** – Laboratory testing
• **Task 5** – Performance monitoring and reporting
• **Task 6** – Instrumentation
• **Task 7** – Pavement design criteria
• **Task 8 & 9** – Draft/final report
## TEST CELLS

<table>
<thead>
<tr>
<th></th>
<th>Recycled Aggregate Base</th>
<th>Large Stone Subbase</th>
<th>Large Stone Subbase with Geosynthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.5 in Superpave</td>
<td>3.5 in Superpave</td>
<td>3.5 in Superpave</td>
</tr>
<tr>
<td></td>
<td>12 in Coarse RCA</td>
<td>12 in Fine RCA</td>
<td>12 in RCA+RAP</td>
</tr>
<tr>
<td>185</td>
<td>3.5 in S. Granular</td>
<td>3.5 in S. Granular</td>
<td>3.5 in S. Granular</td>
</tr>
<tr>
<td>S. Granular Borrow</td>
<td>18 in LSSB (1 lift)</td>
<td>18 in LSSB (1 lift)</td>
<td>9 in LSSB</td>
</tr>
<tr>
<td></td>
<td>TX</td>
<td>TX+GT</td>
<td>BX+GT</td>
</tr>
<tr>
<td></td>
<td>Clay Loam</td>
<td>Clay Loam</td>
<td>Clay Loam</td>
</tr>
<tr>
<td></td>
<td>Clay Loam</td>
<td>Clay Loam</td>
<td>Clay Loam</td>
</tr>
</tbody>
</table>

S. Granular Borrow = Select Granular Borrow

TX = Triaxial Geogrid
BX = Biaxial Geogrid
GT = Nonwoven Geotextile
MATERIALS

- Sand Subgrade
- Clay Loam
- Select Granular Borrow
- LSSB
- Coarse RCA
- Fine RCA
- Limestone
- RCA+RAP
- Class 6 Aggregate
- Class 5Q Aggregate

1 in (25.4 mm)
**TASK 7**

**Outline**

- Compare preliminary (during construction) and long-term performance (after construction)
  - Falling weight deflectometer (FWD)
  - Rutting
**TASK 7**

**Outline**

- Summarize field and laboratory test results and establish correlations between laboratory and field test results

**Laboratory Tests**

- **Index properties**
  - Classification of the materials
  - Specific gravity ($G_s$) and absorption
  - Proctor compaction
  - Asphalt binder & residual mortar contents
  - Water repellency

- **Saturated and unsaturated properties**
  - Permeability ($K_{sat}$)
  - Soil water characteristic curve (SWCC)

- **Stereophotography**
  - Particle size & shape analysis

- **Gyratory compaction and abrasion**
  - Abrasion on the particle size & shape

**Field Tests**

- **During construction**
  - Nuclear density gauge
  - Dynamic cone penetrometer (DCP)
  - Lightweight deflectometer (LWD)
  - Gas permeameter (GPT) test
  - Intelligent compaction (IC)
  - Falling weight deflectometer (FWD)

- **After construction**
  - Falling weight deflectometer (FWD)
  - Frost heave & thaw settlement
  - Rutting
  - International roughness index (IRI)
  - Pavement distresses
Outline

• Develop methods to estimate stiffness and hydraulic properties
TASK 7

Outline

• Permeability vs. gradation

\[ k = 448758 D_{eff}^{3.82} \]

\[ k = 815.89e^{-0.112Cu} \]
\[ R^2 = 0.79 \]

\[ k = 922.41e^{-0.891F} \]
\[ R^2 = 0.77 \]

(Ghabchi et al. 2015)
TASK 7

Outline

- Stiffness vs. particle shape

(Rong et al. 2013)
TASK 7

Outline

• Suction vs. stiffness
  – Base and subgrade materials

(Chu 2020)
## TASK 7

### Outline

<table>
<thead>
<tr>
<th>Materials</th>
<th>Compaction Characteristics</th>
<th>Correlation Equations</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCA</td>
<td>$W_{\text{opt}}$ (%)</td>
<td>$-0.064 \times Cu + 0.763 \times Absorption(%) + 7.75$</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>$\gamma_{d_{\text{max}}}$ (kN/m$^3$)</td>
<td>$-0.374 \times W_{\text{opt}}(%) + 23.6$</td>
<td>0.83</td>
</tr>
<tr>
<td>RAP</td>
<td>$W_{\text{opt}}$ (%)</td>
<td>$-0.0626 \times Cu - 1.349 \times Absorption(%) + 9.84$</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>$\gamma_{d_{\text{max}}}$ (kN/m$^3$)</td>
<td>$-0.289 \times W_{\text{opt}}(%) + 22.42$</td>
<td>0.83</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Materials</th>
<th>Summary Resilient Modulus (SRM) (Mpa)</th>
<th>Correlation Equations</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCA</td>
<td>$\text{SMR}_{\text{EXT}}$</td>
<td>$171.646 - (3.482 \times D_{30}) + (22.378 \times \text{Impurities} %)$</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>$\text{SMR}_{\text{INT}}$</td>
<td>$14683.478 - (36.764 \times D_{30}) - (72.719 \times W_{\text{opt}})$</td>
<td>0.89</td>
</tr>
<tr>
<td>RAP</td>
<td>$\text{SMR}_{\text{EXT}}$</td>
<td>$(117.493 \times D_{30}) + (19.472 \times \gamma_{d_{\text{max}}} + (27.128 \times \text{Asphalt Content(%)}) - (18.510 \times Absorption(%)) - 427.329$</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>$\text{SMR}_{\text{INT}}$</td>
<td>$(-2268.783 - (285.884 \times \text{Fines} %) + (628.742 \times \text{Asphalt content (%)}) + (201.107 \times D_{60}) - (483.158 \times G_5) - (58.243 \times \text{Absorption (%)})$</td>
<td>0.99</td>
</tr>
</tbody>
</table>

(Edil et al. 2012)
TASK 7

Outline

• Analyze the effects of frost depth & number of F-T cycles

(Edil et al. 2017)

(Zhang 2016)
TASK 7

Outline

• Recommend construction specifications
  – Gradation of RCA
    • Residual mortar content
    • Unhydrated cement content
    • Absorption and hydrophilicity
    • Abrasion
    • Degree of compaction
    • Drainage properties
  – Asphalt content & hydrophobicity
  – Stress-hardening & stress-softening behaviors
  – Stresses at layer interfaces (asphalt/base & base+subbase/subgrade)
  – Thermal properties & frost penetration depth
  – Effects of geosynthetics
TASK 7

Outline

• AASHTOWare Pavement ME Design
  – Different thicknesses
  – Different subgrade layers (sand & clay loam)

• Recommend pavement design input values for each NRRA state per their pavement design methods
Thank You!

QUESTIONS??